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# CSERIAC GATEWAY

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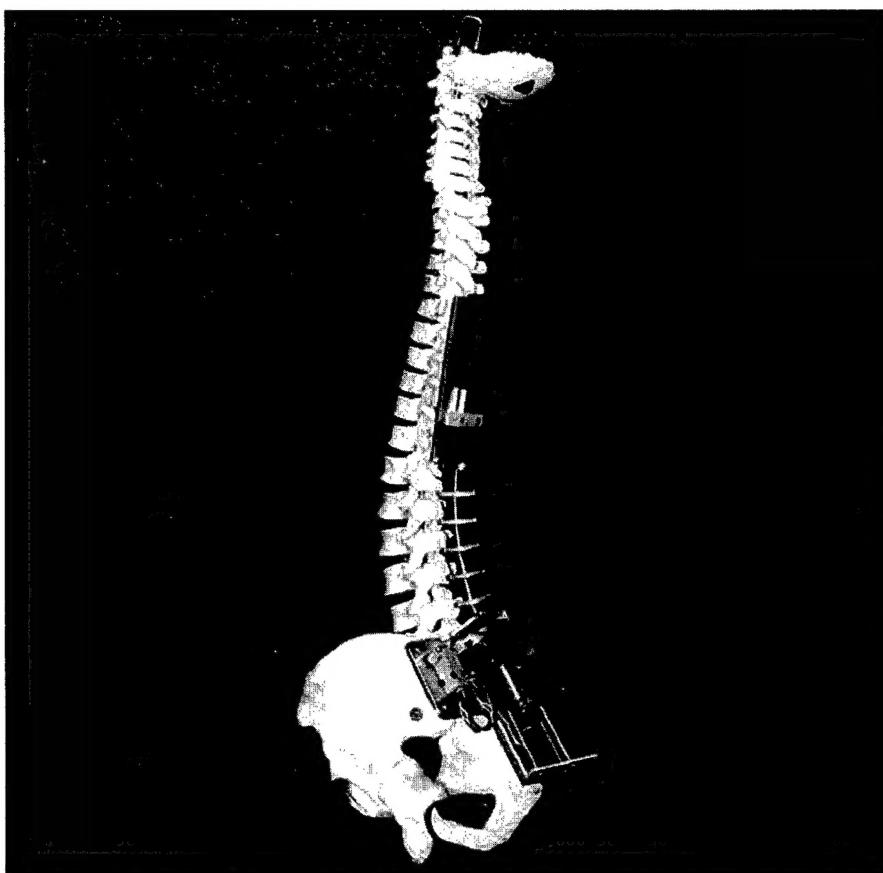


Figure 1. The Lumbar Motion Monitor measures the position, velocity, and acceleration of the spine in the sagittal, lateral, and twisting planes. Digital photo-imaging by David W. Radabaugh.

## The Lumbar Motion Monitor A Tool for the Assessment of Occupationally Related Low-Back Disorder Risk and the Quantification of Spine Status

### DISTRIBUTION STATEMENT A

William S. Marras

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**L**ow-back disorders (LBD) are the most common, expensive, and debilitating occupationally related injuries. According to Andersson (1981), LBDs affect an estimated 80% of the population during their working career. The National Center for Health Statistics has documented that LBDs are the prime reason for activity limitation for those under 45 years of age. Cats-Baril and Frymoyer (1991) have shown that LBDs cost society 25 to 95 billion dollars annually. The Ohio State University Biodynamics Laboratory has developed

*Continued on page 2*

oped a tool to help predict and prevent the occurrence of LBDs, that could potentially prevent thousands of painful and crippling injuries and save American businesses billions of dollars annually. Additionally, we have defined a method for accurately quantifying the extent of these disorders which can lead to more effective treatment and reduce the chance of reinjury.

A number of epidemiologic studies have identified a link between dynamic lifting and LBD risk. Asymmetric postures, sudden movements, twisting, and repetition were all found to be factors in low-back injuries. These studies did not, however, quantify the degree of motion that leads to increased LBD risk. In other words, they have not answered the question "how much exposure to a risk factor is too much?" Hence, we traditionally have had no information about the relationship between LBD risk and trunk movement. Quantification of this risk-motion would provide valuable insight on the design of the work environment and help prevent future back injuries.

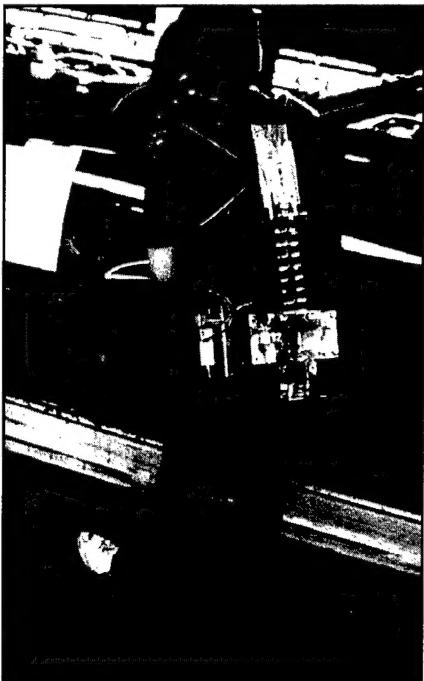


Figure 2. The LMM can easily be worn in industrial environments.

Occupational, motion-based studies of the lumbar spine have historically been limited by the technical inability to gather motion data under actual working conditions. In the past, video-based systems were the most common motion analysis tools. However, it is difficult, if not impossible, to successfully use 3-dimensional video-based motion analysis in many occupational environments. Video assessments must take place in a calibrated space of usually no more than 2-3 cubic meters, cameras must be carefully placed to obtain data for all three planes of motion, and time-consuming analysis is necessary to obtain usable data. Tasks often involve movement outside the calibrated space, work areas limit camera placement, and large amounts of videotape must be carefully analyzed to gather a few minutes of usable data. Therefore, video-based motion analysis systems did not offer a viable way of routinely studying a large number of industrial jobs.

### The Lumbar Motion Monitor

In response to the need for accurate measurements of occupational lumbar motion, the Lumbar Motion Monitor (LMM) (see Fig. 1) was developed at the Biodynamics Laboratory under a grant from the Ohio Bureau of Workers' Compensation. Covered under patent numbers 5,012,819 and 5,094,249, the LMM is a tri-axial electrogoniometer of the lumbar spine that uses four potentiometers to measure the position, velocity, and acceleration of the spine in the sagittal, lateral, and twisting planes. The LMM is attached by chest and waist harnesses which position it on the subject's back directly in line with the spine. Its lightweight construction and relatively small size do not interfere with task performance in the industrial environment (see Fig. 2).

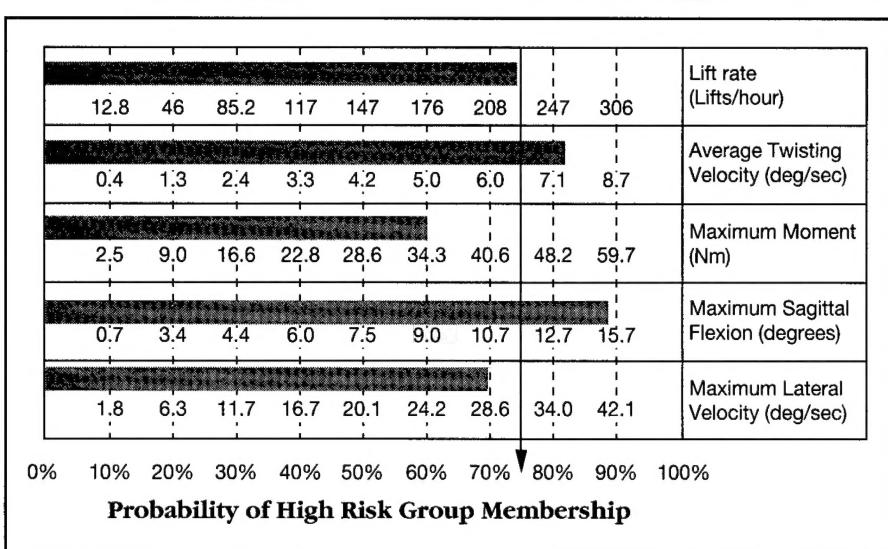
Data from the LMM are transmitted by hardwire or radio telemetry to a microcomputer for storage and analysis. The LMM documents not only the

worker's trunk position as a function of time, but also computes thoracolumbar velocity and acceleration profiles in all three planes of motion. Two projects performed using this device have developed methodologies for (1) controlling back injury risk in the workplace and (2) quantifying the extent of a low-back disorder once an injury occurs.

### Occupational Injury Risk Assessment

A study using the LMM was undertaken to determine the degree of motion leading to increased LBD risk. Over 400 repetitive, manual materials-handling jobs were studied in 48 different industries in the Midwestern United States. The jobs were selected using data from the participating company's OSHA 200 logs and medical records. Based on historical injury rates over a three-year period, high- and low-risk jobs were identified for study. Information from the workplace (heights, weights, etc.) and LMM trunk motion data were collected over a six-year period to form a database of 114 variables for each of the 400 plus jobs.

A five-variable LBD risk model (see Fig. 3) was developed using this database of occupational motions. The model consists of five workplace and dynamic trunk variables observed during the work cycle: lift rate, maximum moment, average twisting velocity, maximum sagittal flexion, and maximum lateral velocity. Together, these five variables predict the probability of membership in the high LBD risk group. This model was found to be nearly four times more accurate than conventional (static) lifting guides and nearly 11 times better than chance (odds ratio). This dramatic increase in accuracy demonstrates the importance of considering dynamic trunk motion when evaluating LBD risk. The risk model is currently being validated in a prospective study in over 21 industries. Preliminary data indicate that this model is at least as predictive as originally thought.



*Figure 3. The five risk-model variables scaled relative to risk. The arrow points to the overall probability of high risk of LBD group membership for a particular job.*

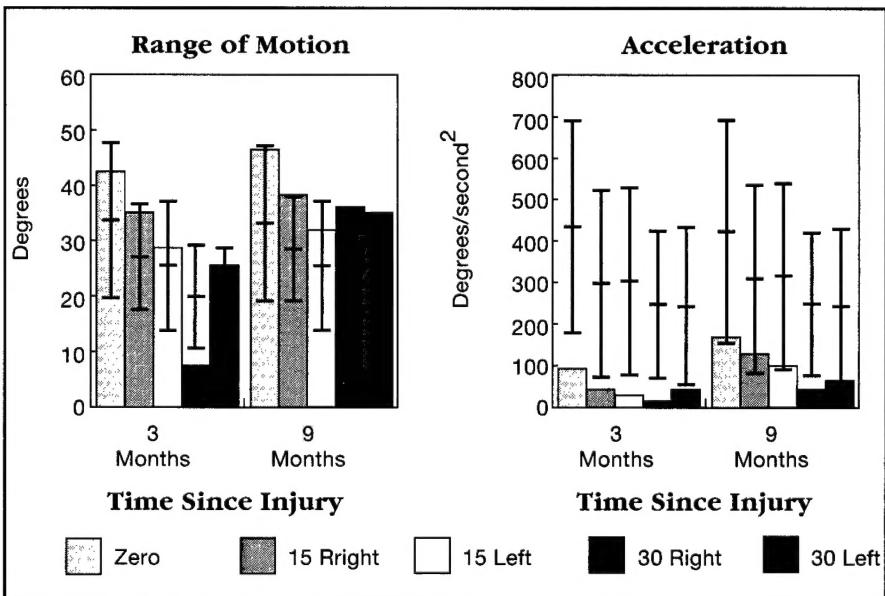
The risk model overcomes many traditional limitations in the analysis and redesign of the work environment. In the past, it was impossible to accurately identify which elements of a job led to an increase in risk. Entire jobs were automated in an expensive attempt at reducing injury risk. The risk model can be used to identify which particular task elements contribute to an increase in LBD risk and thus which elements need to be changed. It is important to understand that LBD risk can never be completely eliminated, but by quantifying risk levels, the model can help determine if a job is within acceptable levels of risk. It can additionally provide a "benchmark" of LBD risk for a job, allowing comparisons between the original design and possible job alterations. Potential job modifications can then be "mocked up" and tested to see if they will effectively reduce LBD risk, eliminating years of waiting to see if injury rates are reduced.

## Clinical Assessment of Lumbar Spine Injuries

The LMM can also be applied to the clinical evaluation of lumbar spine injuries. Accurate assessments of LBD are important to precisely quantify the extent of a disorder, administer proper

tus. Since the trunk's muscle system must coordinate precisely to produce the trunk position, velocity, and acceleration profiles that have developed over time, we believe that documenting this trunk motion signature can provide a non-invasive "window" of the trunk's status.

We have developed a testing protocol designed to observe these natural motion patterns. During the test, subjects wearing the LMM flex and extend their trunk without handling any weight. A normal database was created using 350 male and female uninjured subjects that varied in age from 20 to 70. In this way, we were able to quantify how the motion patterns changed as a function of gender and age. We also tested 171 LBD patients using the same protocol (while compensating for age and gender) to determine how their performance changed with injury. Surprisingly, there was no difference in range of motion. However, dramatic differences were noted in trunk velocity and acceleration signatures. We also noted that as patients recovered, velocity and ac-



*Figure 4. Range of motion (ROM) and acceleration in the sagittal plane compared to normal subjects (SD bars) as a function of time since injury for a patient suffering from a herniated disc. Different columns show motion in various planes of action (i.e., 0, 15 Right, etc.). Notice the deficit in ROM for 30 Right (site of herniation) at 3 months after injury. Nine months after injury, ROM is back within normal range. Acceleration, however, is much slower in returning to the normal range.*

*Continued on page 4*

celeration signatures became more like those of the normal group (see Fig. 4). Thus these velocity and acceleration profiles can also serve as benchmarks of the recovery process. In addition, we have shown that we can also assess sincerity of effort using this technique.

This information can be used for several purposes. First, it can quantify the extent of an injury so that appropriate treatment modalities can be incorporated. Second, it can serve as a benchmark of progress for return visits to the physician and for judging the adequacy of treatment modalities. Finally, it can be used to identify when a patient is ready to return to work with minimal risk of re-injury.

## Conclusion

In the face of global competition and rising health care and worker's compensation costs, it is increasingly important to accurately assess both the risk of occupational injury and the degree of injury so that appropriate treatment can be specified. While traditional ergonomic and clinical methods have relied on static range-of-motion and position

information as the basis for such assessment, new technologies must consider the dynamic motions of the trunk. One such technology is the Lumbar Motion Monitor. It is the first device to add realism to these assessments by documenting the dynamic motion effects of the spine. ●

*William S. Marras, Ph.D., is the Director of the Biodynamics Laboratory, The Ohio State University, Columbus, OH.*

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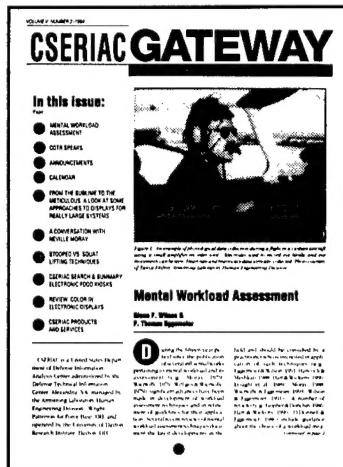
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## Calendar

<b>April 23-27, 1995</b> <b>Columbus, OH, USA</b> Eighth International Symposium on Aviation Psychology. Contact Dr. Richard S. Jensen, Symposium Chair, or Lori A. Rakovan, Technical Chair, The Ohio State University Department of Aviation, Aviation Building, 164 West 19th Avenue, Columbus, OH 43210; (614) 292-2405, fax (614) 292-1014.	<b>May 7-11, 1995</b> <b>Denver, CO, USA</b> CHI '95. Contact CHI '95 Conference Office, 703 Giddings Ave., Suite U-3, Annapolis, MD 21401; (410) 263-5382, fax (410) 267-0332, email: chi95-office@sigchi.acm.org.	<b>June 19, 1995</b> <b>Orlando, FL, USA</b> Safety Technology 2000. Contact American Society of Safety Engineers, 1800 E. Oakton St., Des Plaines, IL 60018-2187; (708) 692-4121.
<b>April 24-28, 1995</b> <b>Dayton, OH, USA</b> 6th Annual Aerospace Atlantic Conference & Exposition, "Partnering for a Lean Aerospace Environment." Sponsored by SAE. For papers, contact Ms. Karen Mong, SAE Aerospace Atlantic '95, 400 Commonwealth Dr., Warrendale, PA 15096; fax (412) 776-1830. For exhibits, contact Mr. Patrick Cantini, SAE Exhibits Division at (412) 772-7174.	<b>May 8-12, 1995</b> <b>Ann Arbor, MI, USA</b> Occupational Ergonomics. A course offered by the University of Michigan. Contact Engineering Conferences, 800 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109-2092; (313) 764-8490, fax (313) 936-0253.	<b>June 19-22, 1995</b> <b>Orlando, FL, USA</b> American Society of Safety Engineers 34th Professional Development Conference and Exposition. Contact American Society of Safety Engineers, 1800 E. Oakton St., Des Plaines, IL 60018-2187; (708) 692-4121 ext. 223, fax (708) 296-3769.
<b>May 1-4, 1995</b> <b>Colorado Springs, CO, USA</b> 34th Meeting of the Department of Defense Human Factors Engineering Technical Advisory Group. Contact Dr. Joe McDaniel, AL/CFHD, 2255 H Street, Wright-Patterson AFB, OH 45433-7022; (513) 255-2558, DSN 785-2558, fax (513) 255-9198.	<b>May 22-24, 1995</b> <b>San Jose, CA, USA</b> Silicon Valley Ergonomics Conference & Exposition (ErgoCon '95). Contact Dr. Abbas Moallem, Program Chair, ErgoCon '95, One Washington Square, San Jose, CA 95192-0180; (408) 924-4132, fax (408) 924-4153. For exhibits, contact the ErgoCon '95 Coordinator, 2603 Main Street, Suite 690, Irvine, CA 92714; (714) 752-7866, fax (714) 752-7444.	<b>June 27-29, 1995</b> <b>Cambridge, MA, USA</b> The 6th IFAC/IFIPS/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Man-Machine Systems. This meeting, held at the Massachusetts Institute of Technology, will be the first held in the United States. Contact Dr. Thomas Sheridan via fax (617) 258-6575 or email: sheridan@mit.edu. Or contact R. John Hansman, Jr. via fax (617) 253-2271 or email: rjhans@mit.edu.
<b>May 3-5, 1995</b> <b>Ann Arbor, MI, USA</b> Ergonomics: Job Analysis and Field Studies. A course offered by the University of Michigan. Contact Engineering Conferences, 800 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109-2092; (313) 764-8490, fax (313) 936-0253.	<b>June 13-16, 1995</b> <b>Seattle, WA, USA</b> The 1995 Industrial Ergonomics and Safety Conference. Contact Dr. Alvah Bittner, Battelle, P.O. Box C5395, 4000 N.E. 41st Street, Seattle, WA 98105-5428; fax (206) 528-3552.	<b>September 24-28, 1995</b> <b>Montréal, Québec, Canada</b> 2nd International Scientific Conference on Prevention of Work-Related Musculoskeletal Disorders, PREMUS 95. Organized by the Institut de recherche en santé et en sécurité du travail du Québec (IRSST) under the auspices of the Scientific Committee on Musculoskeletal Disorders of the International Commission on Occupational Health. Contact IRSST, 505, Boulevard de Maisonneuve Ouest, Montréal, Québec, Canada, H3A 3C2; (514) 288-1551, fax (514) 288-7636.

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## Announcements

<b>New Release From the Human Factors and Ergonomics Society</b>  The Human Factors and Ergonomics Society (HFES) is proud to announce the publication of <i>Anthropometric Methods: Designing to Fit the Human Body</i> by John A. Roebuck, Jr., an internationally recognized expert on anthropometry and its applications.  The book describes traditional and new technology for performing measurements, summarizing data, and analyzing and	presenting those data prior to their integration into simulations. It also enables designers to develop design requirements and evaluate prototypes.  <i>Anthropometric Methods</i> covers the following topics:  Preparing for measurements Devices and procedures for measuring Reporting statistical results Forecasting and estimating Tools for applications Work space design and evaluation	Design/evaluation of tools and equipment Clothing design  In addition are references, glossary, appendices, and index.  The text is 51/2" x 81/2", paperbound, and 200 pages (ISBN 0-945289-01-4). The cost is \$15 US for HFES members and \$20 US for nonmembers; \$5 US is charged for shipping/handling. If applicable, California sales tax will be added. Quantity discounts are available. To request a review copy, please contact HFES at (313) 394-1811.
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## The COTR Speaks

Reuben "Lew" Hann

**P**reventing task-related low-back problems has often been a challenge for human factors and ergonomics specialists. The traditional methods have used models based on data derived from static range of motion studies. However, Dr. William Marras of The Ohio State University Biodynamics Laboratory has developed a model based on dynamic motions of the trunk which more closely approximates real-world situations in which back injuries can occur. In our feature article for this issue, Dr. Marras discusses this new approach.

Last winter, we were fortunate to

have a world-renowned vision expert, Dr. Colin Blakemore from the University of Oxford, England, to inaugurate the 1994 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. He presented a lecture on binocular rivalry which Dr. Brian Tsou of the Visual Display Systems Branch summarizes in this issue. During his visit, I had the opportunity to talk with Dr. Blakemore and an edited transcript of that interview follows the synopsis of the lecture.

A new software product from our Human Engineering Division, Tools for Automated Knowledge En-

gineering (TAKE), is discussed by Lt. Stephanie Lind, formerly of the Crew Station Integration Branch. Since her departure for the Air Force Operational Test and Evaluation Center at Kirtland Air Force Base, Dr. Mike McNeese has assumed responsibility for that project. While the final product will not be available until June 1995, demonstration copies are available now.

In the previous two issues of *Gateway*, articles were written about the most frequently used services CSERIAC offers: the Search & Summary and the Review & Analysis. In this issue, we present information

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about another important service, the Technical Area Task (TAT). Four members of CSERIAC's TAT staff have joined forces to explain more about this useful and comprehensive service.

For those readers who were excited about last issue's feature article on the research being done in the Computerized Anthropometric Research and Design (CARD) Laboratory, we have an announcement on p. 18 concerning a series of upcoming short courses on 3D Surface Anthropometry presented by the Aerospace Medical Panel of the Advisory Group for Aerospace Research and Development Division of NATO. This same Panel is also presenting a series of short courses on Applied Psychophysiological Research techniques in Aerospace

Systems. An announcement for this appears on p. 19.

Finally, another reminder that CSERIAC now has a Home Page on the Internet World Wide Web. (See the announcement on the facing page for details.) We have just updated and improved the original Home Page, and will be adding more capabilities as time goes by. Please check it out, and watch for new features over the next few months. If you have suggestions for improvement or additions to the CSERIAC Home Page, please let us know. ●

*Reuben "Lew" Hann, Ph.D., is the Contracting Officer's Technical Representative (COTR) who serves as the Government Manager for the CSERIAC Program.*

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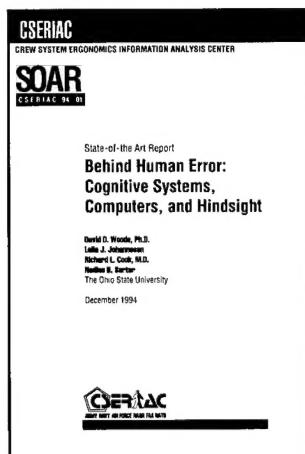
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## ■ Behind Human Error Cognitive Systems, Computers, and Hindsight ■

David D. Woods, Leila J. Johannesen, Richard I. Cook, & Nadine B. Sarter

*The Ohio State University*



Behind Human Error: Cognitive Systems, Computers, and Hindsight (Woods, Johannesen, Cook, and Sarter, 1994).

Accident investigations have often found operators of complex systems to be points of failure, and hence the perception exists that there is a human error problem. This view turns out to be too simplified to allow us to learn from incidents and failures. To learn about the nature of system failure, one must go behind human error by seeing error not as an end point, but as the starting point for investigation. A new state-of-the-art report (SOAR) from CSERIAC investigates what lies behind human error. It explains how outcome knowledge biases our attribution of error. It shows how cognitive system factors play a role in accidents and illustrates the importance of strategic tradeoffs and conflicting goals faced by system operators. It focuses especially on how the design of computers, automation, and other new technology affects the potential for system failure.

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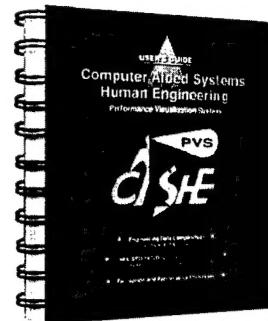
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## Armstrong Laboratory Human Engineering Division Colloquium Series

A Special Presentation of Basic Research

### The Neural Basis of Binocular Rivalry and Strabismic Suppression

**Colin Blakemore**

**Synopsis by Brian Tsou**

*Editor's note: Following is a synopsis of a presentation by Dr. Colin Blakemore, Waynflete Professor of Physiology at the University of Oxford, England, as the first speaker in the 1994 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. This synopsis was prepared by Dr. Brian Tsou of the Human Engineering Division Visual Display Systems Branch. JAL*

In 1613, Father Franciscus Aguilonius of Antwerp, Belgium first recognized that the worlds imaged by each of the two eyes were slightly different because the eyes are a short distance apart. Since then, our remarkable ability to fuse the two disparate images and perceive a single vision of the world in vivid three-dimensional depth and solidity has intrigued philosophers, artists, scientists and, more recently, display engineers. Certain aspects of binocular vision have also greatly influenced research activity within the Human Engineering Division's Visual Display Systems Branch in defining design parameters for a wide field-of-view (large eccentricity) helmet-mounted display. During his lecture on basic research, Dr. Blakemore reviewed briefly the basics of binocular vision and the physiological techniques used to study the problem and, finally, described a new breakthrough from his laboratory.

The locus of points in space which have zero binocular disparity is known as the horopter, a term introduced by Aguilonius himself in 1613. The binocular disparity is defined as the angular

distance from a corresponding point, i.e., the same angular distance both horizontally and vertically from the center of the fovea of each eye, in the two eyes. There is a zone of points in front or behind the horopter over which the image remains fused and single with depth; it has been classically known as Panum's area. Ogle in 1950 measured and showed that Panum's area increases roughly in proportion to retinal eccentricity. Beyond this region the single vision breaks down and the object is perceived as doubled or diplopia, even though, up to a limit, depth is still perceived. Dr. Blakemore in 1970 first reported that disparity discrimination increases in proportion to base disparity in a logarithmic fashion at several eccentricities. Perhaps it shouldn't be a surprise that fusion limit and stereoaucuity increase as a function of eccentricity; after all, monocular visual acuity is known to vary proportionally with eccentricity. It is then quite appropriate for the binocular vision to be matched to the monocular grain of the retina, or the size of retinal receptive field, at each point in the visual field. Receptive field is a physiological concept, as explained by Dr. Blakemore in the lecture, to help in visualizing an organizational representation of the external space seen by a single neuron under recording. Through the impressive advances in this physiological technique, we have gained significant insight into stereoscopic vision.

The neurophysiological analysis of stereopsis is based on the interaction between receptive fields of each eye

as they respond to binocular stimuli. Hubel and Wiesel in 1959 discovered that the activity of neurons in the striate cortex of the cat could be influenced by stimulation of either eye, providing the first physiological evidence for the neural combination of left and right retinal images. In primates, the central visual projections from the retinal ganglion cells of the left and right eyes remain essentially separate up to the input layer 4 of visual area V1, the striate cortex. Beyond that, the vast majority of V1 neurons, and essentially all the neurons in prestriate visual areas, from V2 to V5 (MT), receive inputs from both eyes. The responses of a large proportion of binocular neurons in the visual cortex depend critically upon the relative horizontal position of the two images in the two eyes, an effect called disparity selectivity. Disparity-selective neurons were discovered by Barlow, Blakemore, and Pettigrew in 1967 in the primary visual cortex of the cat. The properties of these cells, as analyzed by Bishop and his collaborators, as well as at other laboratories, are thought to play a basic role in stereopsis, because under conditions of binocular convergent fixation, different cortical neurons would be selectively activated by objects at different relative depths.

Dr. Blakemore went on to explain that such an analysis has elucidated other phenomena including orientation, spatial frequency, and temporal-disparity selectivity; he also emphasized that even though such neural

*Continued on page 10*

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mechanisms form the basis for our perception of the three-dimensional world around us, a complete theory requires much more. For instance, the best observers are able to discriminate 2° of retinal image disparity and since the width of disparity tuning of a single neuron is more than an order of magnitude coarser than that, receptive fields must be "pooled" and some form of autonomous higher-level post processing required. Furthermore, since in a natural scene many objects are outside of Panum's area and are potential stimuli for diplopia, we rarely see diplopia. Thus, some form of inhibition or suppression must be at work in concert with facilitation or fusion. A discussion on a neural basis for suppression based of his most recent experiments highlighted the remainder of Dr. Blakemore's lecture.

In normal binocular vision, one form of suppression of diplopia is referred to as suspension (an interocular inhibitory process that reduces visual information from the suppressed eye below the threshold for conscious perception). Another form of normal suppression occurs when dissimilar targets, that cannot be fused into a single percept, are presented simultaneously to corresponding retinal areas in the two eyes (confusion). Under confusion conditions, an unstable alternating suppression of information from each eye is experienced, which is referred to as binocular rivalry. Binocular rivalry is a remarkably powerful but unexplained visual phenomenon: Conflicting images in the two eyes alternately dominate perception. The neural correlate for binocular rivalry has not been conclusively established. It has been demonstrated that, as Dr. Blakemore remarked earlier, if both eyes are stimulated with contours of similar orientation, most neurons in the visual cortex of normal cats exhibit binocular summation or facilitation, as long as the retinal disparity is optimized: Such interocular facilitation is thought, as we learned earlier in the lecture, to play a part in binocular fusion and stereoscopic vision. On the

other hand, cortical neuron responding to an optimal stimulus in one eye is hardly affected when a stimulus of orthogonal orientation is presented simultaneously in the other eye, even though binocular rivalry or suppression is thought to take place. In other words, no one has shown interocular inhibition under the condition where rivalry occurs. However, Dr. Blakemore reported that, very recently, using a novel procedure devised by himself and his students, they have discovered a compelling neural analog of rivalry in the cat's primary visual cortex.

Dr. Blakemore reported that rivalry may be mediated by reciprocal intercortical inhibition between neighboring ocular dominance columns: The sudden appearance in one eye of a grating stimulus of an inappropriate orientation can suppress the activity of neurons, but only if they are already responding to an optimally oriented pattern through the other eye. He found the majority of the 45 cells studied were clearly suppressed by a grating that is orthogonal in orientation to the optimal *conditioning* grating. The ability of a stimulus introduced into one eye to depress cortical responses elicited through the other eye suggests a possible explanation for the switches in perception that occur in binocular rivalry. He also found that cortical neurons in strabismic cats which lack binocular facilitation exhibit such suppression even with gratings of identical orientation to the conditioning grating. Based on the similarity between normal and strabismic cells, Dr. Blakemore went on to speculate that the powerful interocular suppression as experienced by strabismic humans may be related to binocular rivalry as a way to veto signals from one eye under conditions that would otherwise cause double vision. Dr. Blakemore concluded his lecture by stating that his search for the suppressed neuron to eventually become facilitated again to resemble the on-and-off switching between two eyes' dominance, as in binocular rivalry, was not entirely successful and

further research is required and is continuing.

Based on Dr. Blakemore's most recent evidence on interocular control of neuronal responsiveness for binocular rivalry and the physiological studies that he reviewed, it seems that a more complete theory for binocular vision is much closer in sight than when Dr. Blakemore first studied the subject some thirty years ago. It is our belief that through these advances in binocular vision research we can continue to refine and improve our future binocular helmet-mounted displays so that they will be more comfortable and easier to wear for our pilots. ●

## Recommended Reading

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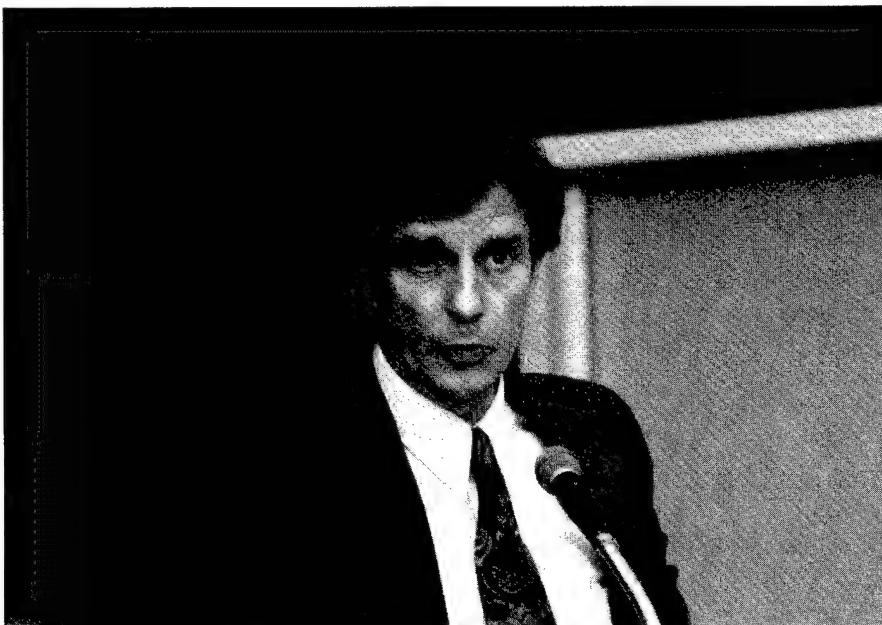
## Request for Topics For State-of-the-Art Reports (SOARS)

CSERIAC makes every effort to be sensitive to the needs of its users. Therefore, we are asking you to suggest possible topics for future SOARS that would be of value to the Human Factors/Ergonomics community. Previous SOARs have included *Hypertext: Prospects and Problems for Crew System Design* by Robert J. Glushko, and *Three Dimensional Displays: Perception, Implication, Applications* by Christopher D. Wickens, Steven Todd, & Karen Seidler. Your input would be greatly appreciated. We are also looking for sponsors of future SOARS. CSERIAC is a contractually convenient, cost-effective means to produce rapid authoritative reports.

Send your suggestions and other replies to:

CSERIAC Program Office  
AL/CFH/CSERIAC Bldg 248  
ATTN: Dr. Ron Schopper,  
Chief Scientist  
2255 H Street  
Wright-Patterson AFB OH  
45433-7022

## Scenes from the Armstrong Laboratory Human Engineering Division Colloquium Series:



Dr. Colin Blakemore, Waynflete Professor of Physiology at the University of Oxford, England, opened the 1994 Colloquium Series with a presentation of his research and theory on the visual phenomenon of binocular rivalry. Photo by Larry Burgess, University of Dayton.



The importance of understanding visual processes, as well as Dr. Blakemore's stature as a world-renowned scientist, drew a large audience that included faculty and students from The Ohio State University, Columbus, OH. Photo by Larry Burgess, University of Dayton.

## Armstrong Laboratory Human Engineering Division Colloquium Series A Conversation With Colin Blakemore

Reuben L. Hann

*Editor's note: Following is an edited transcript of a conversation with Dr. Colin Blakemore, Waynflete Professor of Physiology at the University of Oxford, England as the first speaker in the 1994 Armstrong Laboratory Human Engineering Division Colloquium Series: The Human-Computer Interface. The interviewer was Dr. Lew Hann, CSERIAC COTR. JAL*



**SERIAC:** First, since your research has dealt with issues in the realm of *binocular rivalry*, could you say a bit about this area for the benefit of our readers who might not be familiar with it?

**Dr. Blakemore:** Certainly. Binocular rivalry is a perceptual phenomenon, experienced by all normal people when they view very dissimilar images between the two eyes. It was described in detail by Sir Charles Wheatstone, when he developed the stereoscope in 1838, because that instrument allowed him to put different images into each eye. When we view a normal scene—unless our eyes are misaligned by some optical device such as a prism or by a squint—the images of each individual object in space, lying at roughly the same distance from the observer as the fixation point, fall on roughly corresponding points in the two retinae, and the object is seen as fused. Rivalry occurs when the images on corresponding points are very different. For instance, as Wheatstone showed, if you put a vertically striped pattern in one eye and horizontal stripes in the other, then you don't see a combination of the two: that is, you don't see a gridwork of vertical and horizontal lines. What you see instead is that the field breaks up into patches and within each patch you see either horizontal or vertical lines, almost never

both (See Fig.1). These patches have fluid borders and they shift around in the visual field. Every few seconds the pattern seen within each patch flips to that of the other eye. So it seems as though the signals from each eye are being turned on and off at some point in the visual pathway.

**CSEIAC:** Why would the human visual system function this way? Is there some reason why this might have evolved?

**Dr. Blakemore:** Rivalry can be useful in the real world when there are different images falling on corresponding places in the two retinae. That can and does happen in normal people. For example, if you look at some object far away and hold your finger up close to your nose, the images of your finger do not fall on corresponding points in the two retinae. This is, of course, due to the disparity of the images resulting from the horizontal separation of the eyes. Now, in those circumstances, each image of the finger is accompanied, on the corresponding point in the other retina, by an image of the background. Yet you do not see both the finger and the background: you see either one or the other. So, corresponding regions of the two retinae are constantly being exposed to different stimuli, even during normal viewing, and rivalry then allows the brain to see only one of them at a time. That is I think useful, because it avoids the confusion of information which would occur if one simply saw both images mixed together. Rivalry is a way of switching off input from one eye at a time, in

circumstances where there is conflict between the two images.

The ability to turn off one eye at a time becomes very important in people who have *strabismus* or squint—cross-eyes or wall-eyes. In that situation, the eyes are *always* looking at different things. It would be a disaster for people with that condition if they literally saw the two images superimposed and simply shifted by the angle of squint. The whole world would appear double. If that were the case and you wanted to pick up a particular object, which one would you select, the one seen with the right eye or that seen with the left? What actually happens in such people is that they

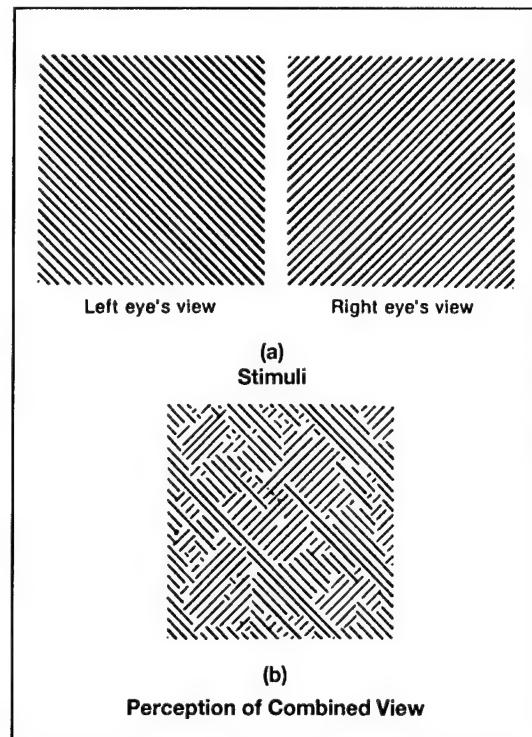


Figure 1. An illustration of binocular rivalry. (From A. Ardit, *Binocular vision*, in K.R. Boff, L. Kaufman, & J.P. Thomas [Eds.], *Handbook of perception and human performance: Vol. I. Sensory processes and perception*. Copyright © 1986 by John Wiley & Sons, Inc. Reprinted with permission.)

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experience very powerful suppression, either alternating between the two eyes (depending on which eye is fixating) or continuously in one eye (the deviating eye). In this case suppression is clearly an adaptive mechanism and there is evidence that it is simply an exaggeration of the natural form of binocular rivalry found in normal people.

Binocular rivalry and strabismic suppression are very powerful perceptual phenomena, which have been described for more than 150 years. They imply that the brain is literally capable of turning off the input from one eye or the other. But surprisingly, when we started our work on this subject, there had been no convincing physiological demonstration of a neural basis for these effects. Despite a huge amount of knowledge about the organization of the visual system, from the eye through to the cerebral cortex, no one had ever shown a clear and convincing effect in neurons that would seem to correlate with the phenomenon of rivalry or suppression. I have been working with a former graduate student, Frank Sengpiel, now a postdoctoral worker in my laboratory, using neurophysiological methods to record from individual nerve cells in different parts of the visual pathway, to try to find cells whose behavior might provide a mechanism for perceptual rivalry.

**CSERIAC:** I understand that the military is now interested in binocular rivalry, as it impacts some optical systems they have been considering.

**Dr. Blakemore:** Yes. In helmet-mounted head-up display systems there is a tradeoff between the resolution of the projected image—using a video system for projection—and the size of the display. The bigger the display, the lower the resolution. It would be very desirable to increase the area of the display without losing resolution. Now, the traditional systems have used full binocular viewing; that is, they have presented pictures through

the helmet system to each eye individually, the same picture in the two eyes. Those are then simply fused perceptually, to generate a single binocular view. But, in this system, one sees only an image which is the same angular width as each individual picture. One trick that has been tried, to enlarge the size of the field without reducing its resolution, is to pull the two images apart, with only a small area of shared overlap in the middle, thereby making the entire display much wider. There is a true, binocularly viewed region in the center, with a continuation of the image into the periphery, seen by only one eye on each side. However, this means that, in regions where only one eye is viewing the stimulus and the other is viewing nothing or the background scene, there is obviously the opportunity for rivalry between the projected stimulus and the blank field or the background. In principle, that could be very disturbing, leading to "blinking out" of the projected display. So, it would be nice to know how rivalry is controlled in the brain and especially how it operates in the peripheral field, to see if there is some way of overcoming this problem, so as to allow extension of the field of view in these head-up display systems.

**CSERIAC:** Finally, I always like to ask our colloquium speakers what type

many questions remaining that can only be fully understood by studying human beings. These include the organization of language; how attention is regulated 'voluntarily' within the brain; and, ultimately, even what consciousness, awareness, perception, choice and thought are. All of those things—even though we have gained some insight into them through the study of animals—require much better techniques for looking at the *human* brain.

Now, there's great promise in the field of imaging the human brain, with some wonderful work using PET (Positron Emission Tomography), and multiple-electrode recording, such as that shown to me here at Armstrong Laboratory by Dr. Glenn Wilson. We have learned a great deal with these techniques, but everybody agrees that each of them is deficient in one way or another. They lack either sufficient spatial or sufficient temporal resolution to be able to see what's going on in the human brain with the detail that we would like.

So, if I had unlimited funds I would concentrate on a new technique of imaging the human brain based on Magnetic Resonance Imaging—functional MRI, as it's called. Functional MRI has shown great promise. It allows you to look at activity in the living human brain. It is truly non-invasive (PET, on the other hand, involves radioactive materials, so there are ethical problems in using it). It's quite fast, compared to PET, providing good temporal resolution. In principle, with big

enough magnets, it can provide extremely high spatial resolution, down to the micron level. So, I think that in the next decade or so, we might see new techniques for looking at the human brain at the level of circuits of individual nerve cells. This, of course, is very exciting, and I would put my money on it. ●

**"Binocular rivalry and strabismic suppression are very powerful perceptual phenomena, which have been described for more than 150 years. They imply that the brain is literally capable of turning off the input from one eye or the other."**

of research they would pursue, if they were provided with unlimited funds. How would you invest this large, hypothetical research grant?

**Dr. Blakemore:** Well, we are all ultimately interested in the human brain, and while we have learned a great deal about how the human brain *probably* works, by studying animals, there are

# Tools for Automated Knowledge Engineering (TAKE)

Lt. Stephanie Lind

**O**ne of the most difficult phases of designing a system is knowledge acquisition. Traditional methods tend to bias a domain expert simply through the question being asked. Important information the domain expert has may not be accessed due to poor questions or the absence of a question altogether. Concept mapping was developed to help alleviate this problem. Concept mapping is a graphic, interactive interviewing technique where the knowledge engineer asks a broad question and allows the domain expert to speak uninterrupted about a topic. In general, an initial question is asked such as "How do you do your job?" or "How does the system work?" and the domain expert is allowed to talk through the subject until he/she feels it has been thoroughly explained. Only if something is confusing or incomprehensible does the knowledge engineer interrupt to ask for clarification or more detail. The concept map is created in real time on a white board in front of the domain expert. An example map is shown in Figure 1.

This concept map about concept mapping shows several nodes and links. The nodes contain concepts, which are typically objects, actions, or events, and the links contain relational words that explain the relationship between the concepts. This technique provides a shared medium for communication where the domain expert can see how the knowledge engineer is interpreting the information and correct inaccuracies in real time. The domain expert can, and often does, control the creation of the map.

The Tools for Automated Knowledge (TAKE) comprise a methodology that incorporates concept mapping and computer analysis tools to

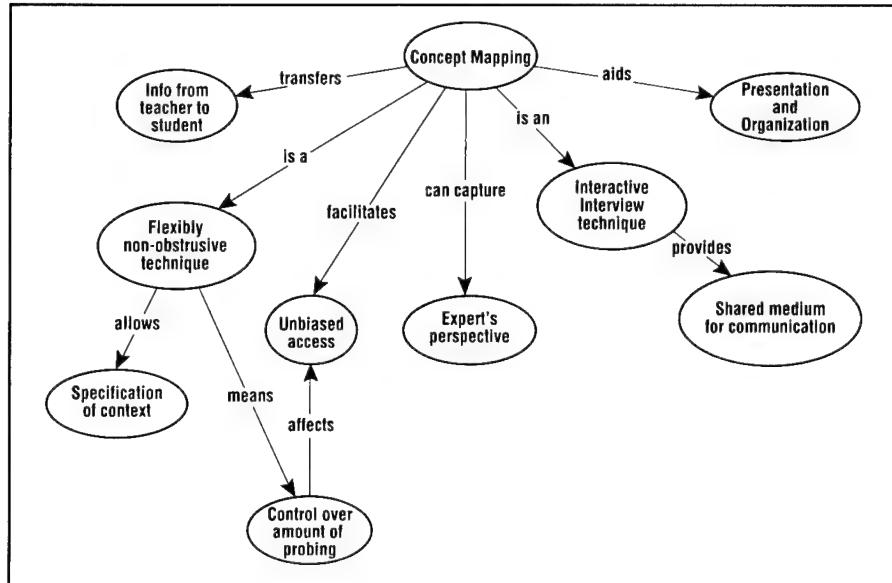


Figure 1. A concept map of concept mapping.

aid in knowledge acquisition and engineering during the early phases of design. TAKE was developed by the Crew Station Integration Branch of the Armstrong Laboratory and New Media, Incorporated.

Once a concept map, or maps, have been created, a component of TAKE known as the Concept Designer is put into use. The Concept Designer has three major functions. These include the *Drawing Function*, the *Outline Function*, and the *Categories Function*. The Drawing Function allows the user to input a map just as it is seen in Figure 1. The Outline Function creates a hierarchical outline of the information in the map. This format of the information can be given to individuals who are not familiar with concept mapping and may find an outline easier to understand. Finally, the Categories Function is the most powerful portion of the program. This function catalogues the data into user-defined categories. The user inputs keywords for each category and the computer searches through the maps

for matches. As many categories as desired can be created and the computer will search through several maps at once as indicated by the user. Categories can also be color coded so that all maps searched will be displayed with colored nodes and links that fall into a particular category.

Several real-world applications have proven the utility of TAKE. The most vivid example was the use during an MH-53J helicopter cockpit evaluation. Several pilots and flight engineers were asked to describe, in detail, the tasks they performed during each phase of the mission. A concept map was created by drawing nodes and links on a white board while the crew member spoke. This gave the crew member a chance to correct any misinterpretations by the interviewer at that time.

Questionnaires were distributed to all crew members. These requested rating information and written comments about several panels in the cockpit. The written comments were concept mapped as well. The maps

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were then entered into the computer using the TAKE software. Then, the Outlining Function of the software was used to combine like crew member information on tasks to create a task analysis. This function was very efficient because all pilot information could be combined, as well as copilot and flight engineer information, into a single document.

In addition, keywords were created for the computer to search on with the Categories Function. Again, this was a time saver because similar problem areas were searched and grouped by the computer. It also provided the human factors engineers with the capability to focus the evaluation by grouping the data and pointing out which areas required more attention. For example, most of the comments from Flight Engineers regarding problem areas dealt with spatial problems. They could not reach instruments or easily operate instruments because they were poorly located. These comments are consistent with the fact that the flight engineer in this aircraft

sits between the pilot and copilot but farther back from the controls. This kind of information also prompted human factors engineers to take cockpit measurements to discover if they met human factors specifications.

TAKE has been validated during several different types of evaluations, including an F-16 switchology study, a Crew-Centered Cockpit Design methodology, and human factors evaluations of the MH-53J and MH-60G helicopter cockpits. The use of TAKE for these diverse examples shows the flexibility of the methodology and the tools. These examples also depict the utility of TAKE in many different disciplines including software engineering, systems acquisitions, human factors engineering, and design engineering.

The concept mapping technique is easily mastered and the computer tools were created to be user-friendly. All members of a design team have used TAKE and found it to be helpful in the design process. For more information about concept mapping or

TAKE, contact:

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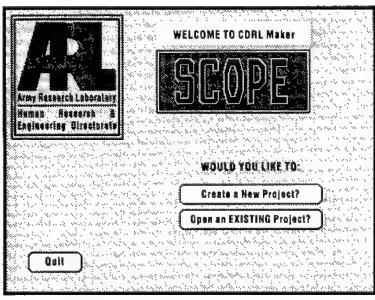
Currently, only demonstration copies of TAKE are available for the Macintosh®. Final versions for both PCs and the Macintosh® will be available in July 1995. For more information, contact:

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*Lt. Stephanie Lind was a Human Factors Engineer with the Crew Systems Integration Branch, Armstrong Laboratory, Human Engineering Division, Wright-Patterson AFB, OH, when this article was written. She is currently with the Air Force Operational Test and Evaluation Center, Kirtland AFB, NM.*

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## CSERIAC Technical Area Tasks An Approach for Solving Your Human Factors Problems

**Michael Reynolds**  
**Laurie Quill**  
**Steve Harper**  
**& Mark Detroit**

In two previous issues of *Gateway*, CSERIAC's Technical Inquiry Services, comprising the Search & Summary and the Review & Analysis, were presented. In this issue, we discuss Technical Area Tasks (TATs). These allow a customer to obtain work that is more in-depth than the Technical Inquiry Service. TATs generally involve systems engineering, analysis, or test and evaluation that are necessary to address the specific human factors concerns of your project.

### What is a TAT?

A TAT can be used to access the wide variety of human factors services, capabilities, and expertise at CSERIAC. A TAT is simply a contract vehicle that provides customers with the capability to tailor CSERIAC's services to meet their unique human factors needs. TATs provide customers with the flexibility to answer a broad spectrum of questions, from a quick response to a specific human factors question to providing long-term engineering and technical support. The CSERIAC charter is defined within a task taxonomy that essentially allows for work in any area involving the human-machine interface (see Table 1).

A CSERIAC TAT offers customers access to the highest quality human factors products and services available anywhere. CSERIAC's in-house staff includes engineers, technical analysts, and systems experts experienced with solving a variety of human factors problems. In addition, CSERIAC is operated by the

University of Dayton Research Institute, providing immediate access to the entire University of Dayton faculty and staff. Further, CSERIAC has an established expert network from which the world's leading human factors subject-matter experts can be accessed. Collectively, these human factors experts working with your professionals can result in the best possible multidisciplinary team to address your human factors needs.

TATs can produce a wide range of human factors-related products and support, such as handbooks, databases, system assessments and recommendations, desktop system emulators, and computer-based analysis tools. CSERIAC's TAT experience includes large-scale full mission aircraft simulation, system design and development, and numerous flight deck modernization efforts. CSERIAC products (software, books, etc.) are frequently used to augment the human factors expertise available on a project.

A few current and past CSERIAC customers include the Federal Aviation Administration (FAA), Nuclear Regulatory Commission (NRC), National Aeronautics and Space Administration (NASA), United States Air Force, as well as a number of other Department of Defense, industrial, and academic organizations. Below are brief descriptions of some current TATs.

A TAT for the FAA has addressed human/pilot factors issues related to the design and certification of flight-deck datalink communications for the FAA's Technical Center. CSERIAC analyzed a database of operational incident reports for potential system

**Table 1.**  
**CSERIAC Taxonomy**

- General Ergonomics
- System Perspectives
- Human Characteristics
- Automation and Human Integration
- Performance-Related Factors
- Environment
- Information Presentation and Communication
- Work Design and Organization
- Display Design and Control
- Health and Safety
- Human-Computer Interfaces
- Society, Economics, and Politics
- Equipment and Vehicle Design
- Methods for Research, Testing, and Evaluation
- Workstation and Facility Design

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design ideas for datalink. CSERIAC has developed reports specific to the FAA flight deck simulations effort; topics include pilot performance measures, simulation fidelity requirements, and simulation facilities requirements. CSERIAC assisted in the planning and execution of a multi-simulator evaluation of a prototype datalink system. The study was designed to assess the benefits of a datalink communications system. Several high-fidelity aircraft simulators were networked into the Air Traffic Control simulation facilities at the FAA Technical Center for the purpose of gathering both system and human performance data over a six-week period from actual pilots and controllers. Future tasks with the FAA are expected to continue this line of research.

In addition, CSERIAC has been supporting the USAF Armstrong Laboratory Logistics Research Division in a series of advanced development concepts related to an Integrated Maintenance Information System (IMIS). The IMIS provides aircraft maintenance technicians with a 4-6 pound, fully ruggedized, self-contained Portable Mainte-

nance Aid (PMA) (i.e., a portable computer). Some of the developmental goals have been to provide a PMA which is easy to operate without training, does not require typing skills, and implements hardware components which can be used under all conditions (e.g., chemical warfare or extreme temperatures). Among the TAT services being provided, CSERIAC has assisted in designing and building a prototyping tool to be used for display of Interactive Electronic Technical Manuals (IETMs). The user interface (designed and built by CSERIAC) was developed using Microsoft Visual Basic Professional® and Microsoft Access®. The User Interface connects with Dynamic Link Libraries (DLL) to access processing functions written in C. Using this package, the Logistics Research Division can readily test new interfaces, software, hardware, and data capabilities and features for various PMA configurations without building an entirely new system.

CSERIAC TATs (and other services) can be accessed in a multitude of ways. Most directly, CSERIAC can ac-

cept purchase orders, checks, money orders, and credit cards (Visa, Mastercard, and Discover). Further, CSERIAC can accept Military Interdepartmental Purchase Requests (MIPR) and other internal transfers of government funds. ●

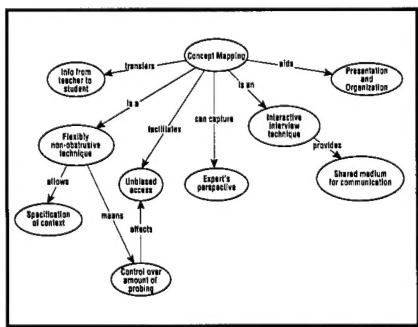
## How Can You Find Out More About TATs?

A series of *Gateway* articles is planned for future issues to discuss these and other CSERIAC TATs in more detail. For additional information or to discuss starting your own TAT, please contact any of the authors at (513) 255-4842; FAX (513) 255-4823; DSN 785-4842; DSN FAX 785-4823; or by email: cseriac@falcon.aamrl.wpafb.af.mil.

*The authors are all TAT project leaders at CSERIAC. Michael Reynolds is a Senior Human Factors Engineer, Laurie Quill is a Senior Human Factors Analyst, Steve Harper is a Senior Design Engineer, and Mark Detroit is a Senior Design Engineer.*

# ■ TAKE A LOOK! ■

## Tools for Automated Knowledge (TAKE) from the Armstrong Laboratory Human Engineering Division



A concept map derived from TAKE

**C**oncept Mapping software for use during system specification and development, user requirement identification, function identification, and task analysis. TAKE is designed to help you map, organize, categorize, and retrieve the volumes of information provided by subject-matter experts and end-users during knowledge elicitation. TAKE runs on a Macintosh Computer System 7.0.

*For further information, contact the CSERIAC Technology Transfer Analyst at (513) 255-4842.*

## 3-D Surface Anthropometry

The Aerospace Medical Panel of the Advisory Group for Aerospace Research and Development division of NATO is sponsoring a 3-day short course on 3-D Surface Anthropometry to be held on three dates at three different locations.

This course presents up-to-date information and guidance regarding three-dimensional (3-D) surface anthropometry technology and the new potential for medicine, human factors engineering, clothing, work spaces, furniture, and personal care items (e.g., eye wear, helmets, gloves, footwear, and other specialty items). The technology provides measuring capabilities which did not previously exist and can be a cheaper, faster, and more reliable way to measure. In addition, this new approach to measurement is more readily transferred to computer-aided design and manufacturing. Specialists will introduce advances in automated data collection methods, visualization, interrogations, and analysis tools, and describe the benefits to specific applications. Recommendations for multi-national 3-D anthropometric surveying will be detailed.

Leading anthropometric specialists contributing as lecturers at the short course include Dr. Peter Jones, United Kingdom; Mr. Hein A.M. Daanen, The Netherlands; Dr. Michael Vannier, United States; Mr. Marc Rioux, Canada; and Ms. Kathleen Robinette, United States.

### Locations:

Motel Bijhorst  
Zijdeweg 54  
2245 BZ Wassenaar  
(The Hague)  
The Netherlands

Socola Military di sanità  
Aeronautica  
(SMSA)  
Via Piero Poggetti 2  
Rome, Italy

GATA  
Military Medical Academy  
Etlik  
Ankara, Turkey

### Dates:

7-9 June 1995

6-8 September 1995

11-13 September 1995

### Enrollment Deadline:

5 May 1995

7 August 1995

7 August 1995

### Points of Contact:

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# GATEWAY

## ■ Applied Psychophysiological Research Techniques in Aerospace Systems ■

The Aerospace Medical Panel of the Advisory Group for Aerospace Research and Development Division (AGARD) of NATO is sponsoring a 3-day short course on Applied Psychophysiological Research Techniques in Aerospace Systems to be held on three dates at three different locations.

The purpose of the short course is to provide an overview of psychophysiological techniques which can be used in aerospace environments for resolving issues related to human factors questions. Examples of these areas include mental workload, fatigue, stress, vigilance, drugs, and environmental factors. Topics will include a general theoretical overview, a discussion of research problems addressed through psychophysiological measures, basic recording and analysis techniques, and operational research examples. As general principles will be covered, people from areas other than aerospace environments who are interested in using psychophysiological measures will benefit from this short course.

The faculty will draw upon their expertise to present instructions on the use of different sensors, how to record and analyze data, including methods used to detect and eliminate common recording problems. Each physiological measure will be covered in detail and will include brain activity, heart rate, hormone measures, eye blinks, and respiration. Demonstrations and/or video-taped examples of techniques will be provided to illustrate specific points. The AGARD Advisory Report #324, *Psychophysiological Assessment Methods*, will be used as the text for the course.

### Locations:

University of Dayton  
300 College Park  
Dayton, OH 45469  
United States

IMASSA/CERMA  
Cite de l'air  
5, Bis Avenue de la Porte de Sevres  
75015  
Paris, France

Military Information Center  
Akershus Castle  
Oslo Mil/Akershus  
0015  
Oslo, Norway

### Dates:

17-19 May 1995

7-9 June 1995

28-30 August 1995

### Enrollment Deadline:

25 April 1995

25 April 1995

28 July 1995

### Points of Contact:

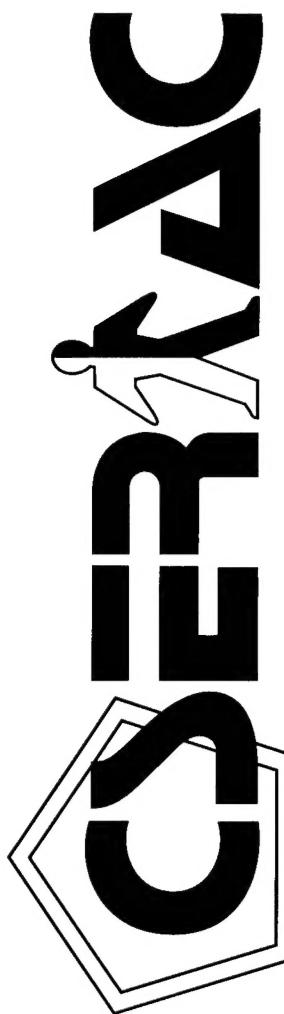
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CSERIAC's objective is to acquire, analyze, and disseminate timely information on crew system ergonomics (CSE). The domain of CSE includes scientific and technical knowledge and data concerning human characteristics, abilities, limitations, physiological needs, performance, body dimensions, biomechanical dynamics, strength, and tolerances. It also encompasses engineering and design data concerning equipment intended to be used, operated, or controlled by crew members.

CSERIAC's principal products and services include:

- technical advice and assistance;

- customized responses to bibliographic inquiries;
- written reviews and analyses in the form of state-of-the-art reports and technology assessments;
- reference resources such as handbooks and data books.

Within its established scope, CSERIAC also:

- organizes and conducts workshops, conferences, symposia, and short courses;
- manages the transfer of technological products between developers and users;
- performs special studies or tasks.

Services are provided on a cost-recovery basis. An initial inquiry to determine available data can be accommodated at no charge. Special tasks require approval by the Government Technical Manager.

To obtain further information or request services, contact:

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